Lestes disjunctus Selys and *L. forcipatus* Rambur (Odonata: Lestidae): Some Solutions for Identification

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ABSTRACT

Five species of the damselfly genus *Lestes* live in British Columbia, Canada, and of these, *Lestes forcipatus* Rambur and *L. disjunctus* Selys are the most similar and most difficult to separate morphologically. Females can be readily distinguished by the size of the ovipositor, but males are difficult to separate. In British Columbia, *L. disjunctus* is the more common, widespread and familiar species. Before 1998, *L. forcipatus* specimens were mistaken for those of *L. disjunctus* because the former is primarily an eastern North American species and because most *Lestes* species are usually identified using male characters. With the discovery that *L. forcipatus* is part of the western fauna, an evaluation of the relative status of the two species in British Columbia is necessary. The best method for separating the two species uses the length of the anterior lamina (part of the secondary genitalia) as a unique character or as part of ratios using other measurements. In addition, in at least western North America, *L. forcipatus* males are more pruinescent than those of *L. disjunctus*, especially on the thorax. Identification using the pruinescence pattern was tested in the field and is recommended as a simple and accurate method for western North America. Soaking Odonata specimens in acetone, a common technique used to preserve colours, damages surface pruinescence and should not be used to preserve mature, pruinescent adults, including those of *Lestes* species. To identify *L disjunctus* and *L. forcipatus* males treated in acetone, it may be necessary to calculate ratios based on various character measurements. Future research should investigate spatial and temporal differences between the species, as well as modes of interspecific communication.

Key Words: Odonata, *Lestes forcipatus, Lestes disjunctus*, identification, British Columbia, pruinescence, acetone, anterior lamina.

INTRODUCTION

Five species of the damselfly genus *Lestes* (Odonata: Zygoptera: Lestidae) occur in British Columbia (BC), Canada: *L. congener* Hagen (Spotted Spreadwing), *L. disjunctus* Selys (Northern Spreadwing), *L. dryas* Kirby (Emerald Spreadwing), *L. forcipatus* Rambur (Sweetflag Spreadwing), and *L. unguiculatus* Hagen (Lyre-tipped Spreadwing). *L. disjunctus* is the most common, widespread and familiar *Lestes* species in the province, and one of the most abundant odonates in Canada, ranging as far north as the Arctic treeline (Cannings 2002). It inhabits many types of standing water habitats with abundant aquatic vegetation and, in southern BC, adults fly from mid-June to mid-October (Cannings 2002).

L. forcipatus is generally much less common than *L. disjunctus,* although it is as abundant in some cold fen habitats, and both species often occur at the same site. *L. forcipatus* does not range as far north as *L. disjunctus* and, although not known from much of BC's north, it has been collected in the southeastern Yukon. In the western Canadian Cordillera, it is most common in sedge fens (Cannings 2002). Walker

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(1953) described *L. forcipatus* habitat in Ontario as "ponds, both temporary and permanent, marshy lakes, and slow, weedy streams". In BC *L. forcipatus* has been collected from mid-June to mid-September (Cannings 2002).

L. forcipatus was not reported in BC until 1998, when it was first collected in the Rocky Mountain Trench north of Golden and subsequently found in many other localities in the southeastern part of the province. However, it probably has long been a resident of the province; it was long overlooked because of its close resemblance to *L. disjunctus* (Ramsay and Cannings 2000). Before 1998, *L. forcipatus* was not known west of Saskatchewan (Walker 1953, Westfall and May 1996), and had just recently been found in Washington State, the first record west of Montana (Ramsay and Cannings 2000). The species is now known from seven counties in that state and one in Idaho (Paulson 2004). By 1999 *L. forcipatus* had been discovered at several other BC locations farther south and west, and by 2000 had been collected on Vancouver Island. Some of our old museum specimens of *L. disjunctus* from many regions of the province have been re-identified as *L. forcipatus,* indicating that museum collections across western Canada probably contain many misidentified specimens.

Males of *L. disjunctus* and *L. forcipatus* are difficult to separate, although numerous characters have been employed in identification (Walker 1953, Westfall and May 1996, Catling 2002, Donnelly 2003). The usual method of distinguishing the two species and confirming their presence at a location is through identification of the females. In *L. forcipatus* females the ovipositor valves reach the tips of the cerci; in *L. disjunctus* they do not (Walker 1953, Cannings 2002) (Fig. 1).

Lestes species are usually brown, black, metallic green or bronze above and mostly pale below; especially in males, the head, thorax, base and tip of abdomen become pruinescent bluish white with age. Pruinescence (pruinosity) is a waxy substance produced by the hypodermis in many groups of Odonata and excreted on the cuticular surface through porous canals (Gorb 1994). Pruinescence is implicated in thermal regulation in dragonflies (Garrison 1976, Paulson 1983) and is thought to play a role in species recognition and intraspecific communication -- indeed, the patterns of pruinescence in males may be a result of sexual selection (Jacobs 1955, Corbet 1999). Therefore, pruinescence patterns might offer good species identification characters, especially in males.

The object of this project was to find novel and definitive distinguishing characteristics between males of *L. disjunctus* and *L. forcipatus*, building on the studies of workers in eastern North America. Thus, we hope (a) to distinguish males in the absence of associated females; (b) to identify, with relative ease, the species in the field, (c) to correct any misidentifications of specimens in BC museum collections; and (d) to establish accurate distributions for both species in BC. The first part of the present work measures certain structures of the male genitalia to find the best features to separate the species. The second part quantifies the degree of pruinescence of adult males of each species.

MATERIALS AND METHODS

Specimens. We measured 50 male *L. disjunctus* and 45 male *L. forcipatus* specimens from localities in BC and Alberta (two *L. disjunctus* only from Alberta) and from Washington and Maine in the United States. Eighty-four of the specimens were from the Royal British Columbia Museum (RBCM), Victoria; the others were borrowed from the Spencer Entomological Museum, UBC, Vancouver, and the Slater Museum of Natural History, Tacoma, WA. A list of the specimens and their collection data is on file at the RBCM and is available on request. Most specimens were *in copula* or in tandem, except for three *L. forcipatus* and one *L. disjunctus*; thus, the

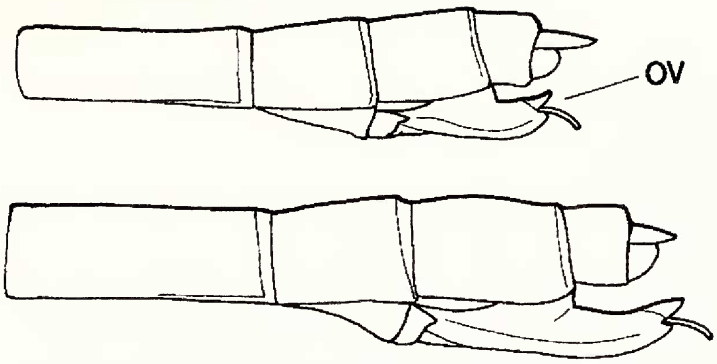

Figure 1. Lateral view of apex of female abdomen. Top, *Lestes disjunctus*; Bottom, *L. forcipatus*. OV = ovipositor.

identities of almost all males were confirmed using the associated females.

Measurements. During examination, each specimen was held by the base of the wings using a small padded alligator clamp soldered to a #7 insect pin. The pin was inserted into a cork mount, and the specimen held in a standardized measuring position. Specimens were examined at 100x magnification and measurements were made to 0.01 mm.

Thirteen characters were measured; terminology follows Westfall and May (1996) and Donnelly (2003).

Cercus (Fig. 2):

1. Distance from base of apical tooth to base of basal tooth (AB).

2. Distance from apex of cercus to base of apical tooth (AC).

3. Distance from swelling at medial base of cercus to base of basal tooth (BB) (not figured).

Secondary genitalia (abdominal segment 2) (Fig. 3):

4. Length of the anterior lamina (anterior hamule) (AL). Walker (1952, 1953) did not explain how to measure the lamina, but Catling (2002) and Donnelly (2003) prefer to measure the ventral length of the hamule from where it appears from above sternite 1. He notes, however, that specimens show different degrees of bending in abdominal segments 1 and 2 and thus there is no good reference for the hamule base. We measured the blade of the lamina only.

5. Length of membranous shield of sperm vesicle (MS) (penis vesicle of Catling (2002) and Donnelly (2003)).

6. Length of penis shaft (PS).

7. Length of sperm vesicle (SV).

Apex of abdominal segment 10 (Fig. 4):

8. Height of apical hood (HT). This structure is a triangular projection on the dorsal apex of abdominal segment 10. The apex of the abdomen was viewed end-on.

9. Width of base of apical hood (HL).

10. Width of the abdomen (WA). The greatest width of the abdomen measured when the apex of the abdomen was viewed end-on.

Other:

11. Length of abdominal segment 2 (S2). Measured in lateral view.

12. Length of abdominal segment 3 (S3). Measured in lateral view.

13. Width of head (HD). The distance between the extreme lateral edges of the eyes, measured dorsally.

We analysed the difference between species for each character measured using a z-test after checking for uniformity of variance, using the MS Excel Data Analysis Tool (Stinson and Dodge 2004).

Pruinescence.

Pterothorax (Fig. 5). We compared the extent of pruinescence on the head, pterothorax (fused mesothorax and metathorax), and abdominal segments 1 to 10 between males of the two species. Pterothoracic pruinescence was divided into several value categories, as follows: absent = 0, low lateral (below interpleural suture) = 1, mid lateral (below midline of mese-

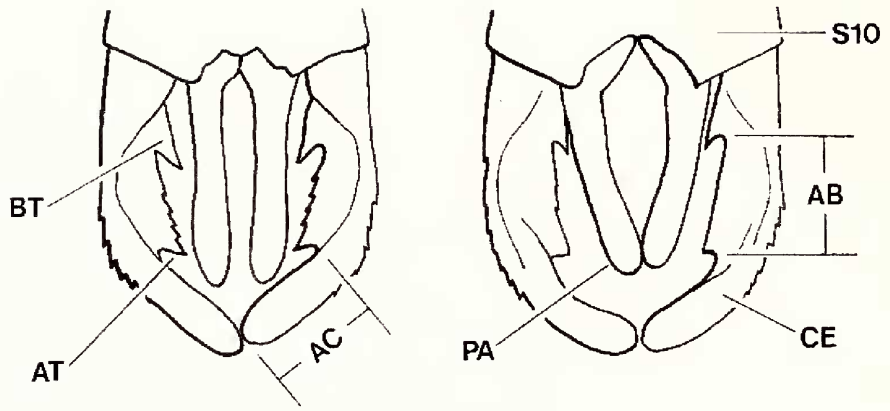

Figure 2. Dorsal view of male primary genitalia. Left, *Lestes disjunctus*; Right, *L. forcipatus*. AB = distance between base of apical tooth and base of basal tooth of cercus, AC = distance between base of apical tooth and apex of cercus, AT = apical tooth of cercus, BT = basal tooth

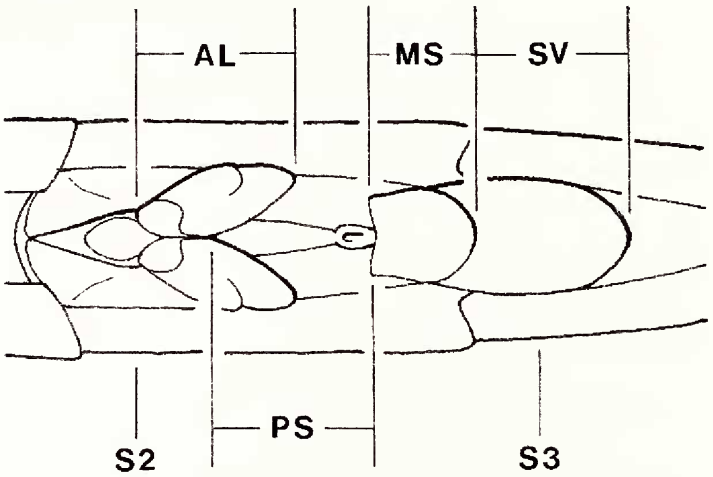

Figure 3. Ventral view of male secondary genitalia. AL = length of blade of anterior lamina, MS = length of membranous shield of sperm vesicle, PS = length of penis shaft, SV = length of sperm vesicle, S2 = abdominal segment 2, S3 = abdominal segment 3.

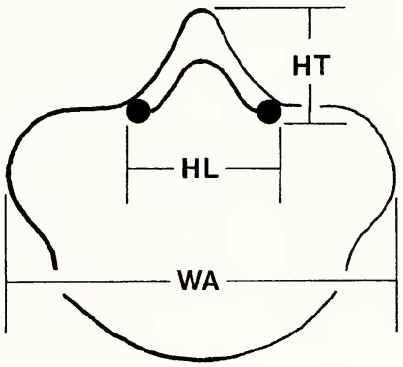

Figure 4. Diagrammatic apical view of abdominal segment 10 of male *Lestes disjunctus*. HT = height of apical hood, HL = width of base of apical hood, WA = width of abdomen.

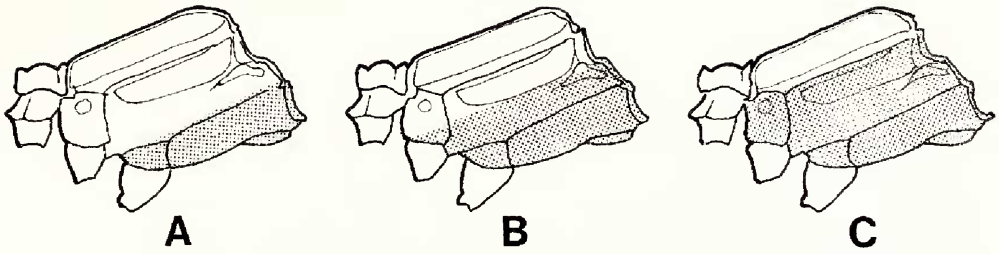

Figure 5. Lateral view of thorax of *Lestes disjunctus* male. Stippling represents coverage of pruinescence: A, low lateral; B, mid lateral; C, complete lateral.

pimeron)= 2, complete lateral (below mesepisternal stripe) = 3, lateral+dorsal (complete lateral plus mesepisternal stripe and dorsal midline) = 4, complete thorax (ventral + lateral + dorsal) = 5. Because specimens had been treated in acetone and the pruinescence patterns were thus damaged, both sides of the pterothorax were compared, and the more pruinescent side recorded.

Abdominal segment 2 (Fig. 6). We examined segment 2 for presence or absence of a rectangular patch free of pruinescence and covering about the apical one-third of the tergite. If the patch was present, we assigned a value of 1; if absent, a value of 0.

RESULTS

Measurements. Nine measurements failed to show a significant difference between the species: AC, BB, HT, HD, MS, PS, S3, SV and WA.

Table 1 summarizes the seven measurements that we consider important to this study; these include the mean, standard deviation, range and significance values for z-tests. In Table 1 the z-test values for the HD, S3, and WA are not significant. However, tests of the same measurements in character ratios show significant differences between the species.

Ratios of character measurements are often useful in preventing individual size variation from obscuring the value of a character when comparing species variation. Analysis showed that several character ratios calculated were not useful in separating the two species: AB/AC, AB/AL, AC/AL, AC/HD, BB/HD, HL/AL, HT/HD, HT/HL, HT/WA, SV/AL, SV/S2, MS/AL, MS/HD, MS/S2, PS/HD, S3/HD, SV/HD, WA/HD. The significant character ratios for both *L. forcipatus* and *L. disjunctus* are summarized in Table 1.

Pruinescence. The head and abdominal segment 1 were pruinescent in all specimens; the pruinescence on segments 3-10 was not significantly different. All comparisons were inconclusive except for those of the pterothorax and abdominal segment 2.

Pterothorax (Table 2). In all specimens of both species, the pterothorax was pruinescent. In *L. forcipatus*, it was completely pruinose (covered ventrally, laterally and dorsally) 72.5% (n = 40) of the time; *L. disjunctus* was never completely pruinescent, and never covered dorsally. *L. forcipatus* was covered completely laterally and dorsally in 20% of specimens but never showed only low lateral or mid lateral pruinescence. Of the 40 specimens measured, three (7.5%) had only the lateral area completely covered. *L. disjunctus* was completely covered laterally 60.0% (n = 30), mid laterally 30%, and low laterally 10% of the time.

Abdominal segment 2. Segment 2 in all *L. forcipatus* specimens had a distinct dorsal bare patch. In *L. disjunctus* an indistinct, different sort of patch was present 23.1% (n = 26) of the time. It was both asymmetrical and lightly pruinescent. The average ± SD patch size (n = 28) in *L. forcipatus* was 0.67 ± 0.13 mm long, by 0.50 ± 0.11 mm wide.

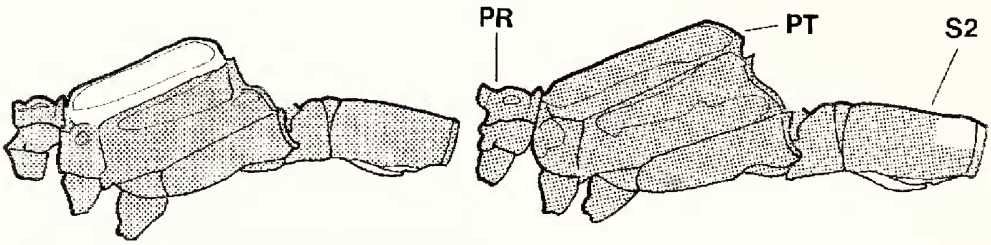

Figure 6. Lateral view of thorax and abdominal segments 1 and 2 of fully pruinescent males. Left, *Lestes disjunctus;* Right, *L. forcipatus*. PR = prothorax, PT = pterothorax, S2 = abdominal segment 2.

Table 1.

Summary statistics of measurements and ratios made for *Lestes forcipatus* and *L. disjunctus*. Two-tailed z-tests were used to compare characters between species. Distances measured are as follows: AB = apical tooth of cercus to basal tooth of cercus, AL = length of blade of anterior hamule, HD = width of head, HL = width of base of apical hood, S2 = lateral length of abdominal segment 2, S3 = lateral length of abdominal segment 3, WA = width of abdomen.

Character	*L. forcipatus*				*L. disjunctus*				z-test results	
Distance	**Mean**	**SD**	**Range**	**n**	**Mean**	**SD**	**Range**	**n**	**z**	**P (Z<=z)**
AB	0.51	0.04	0.47 - 0.60	42	0.45	0.05	0.33 - 0.53	46	6.10	0.00
AL	0.91	0.09	0.67 - 1.20	44	0.72	0.06	0.60 - 1.00	50	11.37	0.00
HD	4.73	0.16	4.33 - 5.00	39	4.77	0.19	4.33 - 5.07	42	-0.89	0.37
HL	0.53	0.06	0.40 - 0.67	41	0.44	0.05	0.33 - 0.53	45	7.42	0.00
S2	2.57	0.16	2.27 - 2.87	44	2.40	0.13	2.13 - 2.67	50	5.47	0.00
S3	4.32	0.24	3.87 - 4.87	44	4.34	0.26	3.93 - 5.00	50	-0.41	0.68
WA	1.27	0.09	1.13 - 1.53	41	1.27	0.10	1.00 - 1.40	45	0.16	0.87
Ratio	**Mean**	**SD**	**Range**	**n**	**Mean**	**SD**	**Range**	**n**	**z**	**P (Z<=z)**
AB/HD	0.11	0.01	0.10 - 0.13	37	0.09	0.01	0.07 - 0.11	40	6.65	0.00
AL/HD	0.19	0.02	0.14 - 0.24	39	0.15	0.01	0.14 - 0.20	42	11.99	0.00
AL/S2	0.35	0.03	0.27 - 0.42	44	0.30	0.03	0.25 - 0.39	49	8.27	0.00
AL/S3	0.21	0.02	0.14 - 0.26	44	0.17	0.01	0.14 - 0.22	49	11.08	0.00
HL/HD	0.11	0.01	0.08 - 0.14	36	0.09	0.01	0.07 - 0.11	38	7.50	0.00
HL/WA	0.42	0.04	0.30 - 0.50	41	0.35	0.04	0.28 - 0.47	45	7.53	0.00
S2/HD	0.55	0.03	0.48 - 0.59	39	0.51	0.02	0. 47 - 0.54	42	7.74	0.00
S2/S3	0.60	0.03	0.52 - 0.64	44	0.55	0.02	0.50 - 0.60	49	8.57	0.00

DISCUSSION

Measurements. The search for diagnostic characters to differentiate *L. forcipatus* males from those of *L. disjunctus* is not a new one. According to Donnelly (2003), the earliest paper that demonstrates a distinction between the two species is by Garman (1917), who illustrated the longer ovipositor in *L. forcipatus*. Montgomery (1941) noted the widespread confusion between the species and cited four diag-

Table 2.
Percentage of specimens of *Lestes forcipatus* and *L. disjunctus* displaying selected patterns of pruinescence on the pterothorax. Figs. 5 and 6 illustrate the patterns.

Pruinosity pattern	*L. forcipatus* % (n=40)	*L. disjunctus* % (n=30)
Lateral-ventral-dorsal	72.5	0
Dorso-lateral	20	0
Complete lateral	7.5	60
Mid lateral	0	30
Low lateral	0	10
Absent	0	0

nostic differences: (1) distance between teeth of cercus; (2) width of apical hood of abdominal segment 10; (3) width of base of membranous shield of sperm vesicle (penis vesicle), and (4) shape of penis (see Donnelly 2003). When Walker (1952) reviewed Montgomery's findings, he rejected the shape of the penis, but retained the other three characters. Walker (1952) added the relative lengths of abdominal segments 2 and 3 and the length of the anterior lamina (see Donnelly 2003). Westfall and May (1996) also base their separation of the species on the relative lengths of abdominal segments 2 and 3, but added the distance between the tip of the basal tooth and the swelling near its base, the shape of the membranous shield of the sperm vesicle and the relative size of the cercal teeth.

Donnelly's (2003) findings are different again. He stressed the use of the anterior lamina length, the distance between the apical and basal teeth on the cercus, the shape of the paraproct and the apical hood width on segment 10. He preferred not to use the membranous shield, the relative lengths of abdominal segments 2 and 3, and the distance from the basal swelling of the cercus to the tip of the basal tooth. Catling's (2002) useful study of Ontario material concluded that the best characters were the relative heights of the apical and basal teeth of the cercus and the relative extent of pale and dark pigment (not pruinescence) on the thorax.

Our findings support the conclusion that it is best to use a combination of characters for identification. In western North America, at least, both morphology and the pattern of pruinescence should be considered. A short review of useful characters and character ratios follows:

1. Anterior lamina (AL). Rather than measuring the whole length of the lamina (including the stalk), we measured the expanded apical blade-like part only. The lamina in *L. forcipatus* is longer (mean = 0.91 mm) than that of *L. disjunctus* (mean = 0.72 mm). The ranges of the lengths of the AL overlap in the two species, but the length in *L. disjunctus* does not exceed 1 mm, while that of *L. forcipatus* reaches 1.20 mm. We found the lamina to be significantly different in three character ratios – those using the head width, the length of segment 2 and the length of segment 3.

2. Base of apical tooth to base of basal tooth (AB). AB is a good identification character as a simple measurement or as a ratio with head width (Table 1). The distance between the teeth is longer in *L. forcipatus* than in *L. disjunctus*; this result is supported by Donnelly (2003). Although there is some overlap in the measurements of the two species (*L. disjunctus,* 0.33 – 0.53 mm; *L. forcipatus,*0.47 – 0.60 mm), the character is useful when used in conjunction with others.

3. Width of the apical hood (HL)

The ranges of apical hood widths overlapped in the two species -- *L. disjunctus* (0.33 – 0.53 mm) and *L. forcipatus* (0.40 – 0.67 mm). The HL is generally greater in

L. forcipatus, which gives the apical hood the wide, low appearance (as opposed to the pinched shape in *L. disjunctus*) that is often used to distinguish the species (Donnelly, 2003, Lam 2004). Based on our data, this is a generalization and is not reliable for differentiating the species. The HL is useful when used in ratios using the head and abdomen.

4. Width of the head (HD). There was no significant difference between the species in the width of the head. We used the measurement to calculate ratios.

5. Lateral lengths of abdominal segments 2 and 3. There was a significant difference between the length of segment 2 in both species; however, the ranges overlapped considerably. Segment 3 was not different between species but the relative lengths of segments 2 and 3 were significant.

6. Width of the abdomen (WA). This measurement is significant only when used in a ratio with measurements of the apical hood. Comparing species using this character is difficult as the ranges overlap greatly.

Pruinescence. The literature from eastern North America, where *L. forcipatus* has been studied for decades, does not mention pruinescence as a basis for separating *L. disjunctus* and *L. forcipatus* (Walker 1952, 1953, Westfall and May 1996, Catling 2002, Donnelly 2003, Lam 2004). In that region, pruinescence patterns are apparently different from those in northwestern North America and are of little use in species identification. On the other hand, as was originally noted in Washington State by Dennis Paulson, (D.R. Paulson, Slater Museum, University of Puget Sound, Tacoma; pers. comm.), in far western North America, pruinescence in mature individuals seems a good character for separating the species. It has the advantage of being easy to use in the field without even having to capture the specimen. Further study of these patterns over the whole range of the two species is required.

Maturity is accompanied by pruinescence on abdominal segments 2, 8, 9, and 10, and to a lesser degree on abdominal segments 3, 6, and 7. Patterns on abdominal segments other than segment 2 are not useful in identification because they are almost identical in shape, intensity and frequency of occurrence in both species. Abdominal segment 2 however, is reliable in differentiating *L. disjunctus* and *L. forcipatus* (Table 2.). Although 23% of *L. disjunctus* appear to have a clear patch at the apex of this segment it has, upon closer inspection, not a clearly defined rectangular shape but an asymmetrical shape with some pruinscence throughout. There was little individual variation in the position of pruinescence in either *L. forcipatus* or *L. disjunctus*.

Conclusions. Even with careful analysis of each character, a specimen lacking pruinescence is difficult to identify. As a general rule, a specimen with longer or wider measurements than the average *L. disjunctus* specimen should be regarded as a potential *L. forcipatus*. The most worthwhile characters to choose for identification are the AB (the distance between the base of the apical tooth and the base of the basal tooth of the circus), AL (the length of the blade of the anterior lamina), HL (the basal width of the apical hood), and S2 (the lateral length of abdominal segment 2). In each, the mean distance is higher in *L. forcipatus* and, although ranges overlap considerably, the range exceeds that of *L. disjunctus*.

The most useful ratios are the above measurements divided by the head width (AB/HD, AL/HD and HL/HD). In AB/HD the ranges of the two species overlap minimally compared to those of the other significant ratios. In the remaining two ratios the range of *L. forcipatus* far exceeds that of *L. disjunctus*.

In our study, any specimen with pruinescence on the dorsum of the pterothorax (mesepisternal stripe plus midline) is *L. forcipatus,* and the species showed this trait in over 90% of the specimens examined. *L. forcipatus* never had only low lateral or mid lateral pruinescence, a common pattern in *L. disjunctus,* and showed complete lateral coverage (without any dorsal

pruinescence) only 7.5% of the time, compared to 60% of *L. disjunctus* specimens. Any specimen with a strongly differentiated, symmetrical, pruinescent-free patch apically on the dorsum of abdominal segment 2 was *L. forcipatus*. The segment in *L. disjunctus* was usually completely pruinescent; about a quarter of the time it was marked with an irregular, lightly pruinescent patch.

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